

(19)



(11)

EP 3 679 415 B1

(12)

EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention
of the grant of the patent:

27.12.2023 Bulletin 2023/52

(51) International Patent Classification (IPC):

G02B 27/00 ^(2006.01) **G01M 11/02** ^(2006.01)
G01N 21/958 ^(2006.01)

(21) Application number: **18782192.1**

(52) Cooperative Patent Classification (CPC):

G02B 27/0075; G01M 11/0257; G01M 11/0278;
G01N 2021/9583

(22) Date of filing: **06.09.2018**

(86) International application number:

PCT/IB2018/056812

(87) International publication number:

WO 2019/049065 (14.03.2019 Gazette 2019/11)

(54) **CONTACT LENS INSPECTION SYSTEM AND METHOD**

KONTAKTLINSENPRÜFSYSTEM UND -VERFAHREN

SYSTÈME ET PROCÉDÉ D'INSPECTION DE LENTILLES DE CONTACT

(84) Designated Contracting States:

AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO
PL PT RO RS SE SI SK SM TR

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(43) Date of publication of application:

15.07.2020 Bulletin 2020/29

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(56) References cited:

EP-A2- 0 686 842 WO-A1-2015/053712
WO-A1-2015/174927 WO-A2-03/071222
WO-A2-2009/148862 DE-A1-102015 201 823

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Description

BACKGROUND

Field of the Invention

[0001] The present invention relates to an inspection method and system for contact lenses.

Background Art

[0002] Cameras and vision systems are often used in inspection systems, particularly to inspect for defects. However, conventional camera lenses may not be accurate and/or adequate for inspecting curved surfaces such as contact lens surfaces, because, typically, in an inspection system, the object of the image is projected onto a flat CCD image plane. A technique used to circumvent this problem is to increase the depth of field of the conventional camera lens by reducing the size of the aperture, while accepting the disadvantages connected with reducing the size of the aperture, such as reduced illumination.

[0003] In specific applications, such as for example, contact lens inspection, reducing the size of the aperture introduces additional difficulties. The significant curvature of a contact lens (sagittal height of about 3.5mm and 14 mm diameter) prevents uniform focus across the surface of the lens. Additionally, for items, such as contact lenses, that float in a liquid solution, when the depth of field is adjusted to capture a 3.5 mm depth, the floating debris in solution is also brought into focus, making inspection techniques inaccurate.

[0004] WO 2009/148862 A2 discloses a contact lens inspection system for soft contact lenses comprising a light source, a camera and a processing unit.

[0005] DE 10 2015 201823 A1 discloses a lens inspection system comprising a light source and a plenoptic camera.

[0006] WO 2015/053712 A1 discloses a contact lens inspection system comprising a light source, an optical system and a camera. The optical system is designed to have a curved depth of focus.

[0007] The present invention seeks to solve the problems listed herein by providing an inspection system and method to improve the ability to inspect defects on curved surfaces. A particular embodiment includes an optical system that is capable of inspecting defects on the surfaces and sides of contact lenses.

SUMMARY

[0008] The present invention suggests an inspection system and a method as it is specified by the features of the independent claims 1 and 3. Advantageous aspects of the system according to the invention are the subject matter of dependent claim 2.

[0009] Throughout the entire specification, including

the appended claims, the singular forms "a", "an", and "the" include the plural, unless the context explicitly dictates otherwise. When using the term "about" with reference to a particular numerical value or a range of values, this is to be understood in the sense that the particular numerical value referred to in connection with the "about" is included and explicitly disclosed, unless the context clearly dictates otherwise. For example, if a range of "about" numerical value a to "about" numerical value b is disclosed, this is to be understood to include and explicitly disclose a range of numerical value a to numerical value b. Also, whenever features are combined with the term "or", the term "or" is to be understood to also include "and" unless it is evident from the specification that the term "or" must be understood as being exclusive.

[0010] According to the invention, the plenoptic camera is adapted for producing a plurality of images, the plenoptic camera having an objective lens, a lenslet array and a photosensors array.

[0011] In particular, the lenslet array comprises a plurality of microlenses.

[0012] In particular, the camera is arranged on that side of the contact lens opposite to the side where the light source is arranged.

[0013] According to the invention, the processing unit is adapted for processing the different views of the contact lens field received by the photodetector to produce a final image.

[0014] In still some further embodiments of the system according to the invention, the processing unit is adapted for producing the final image involving using the different views of the contact lens to adjust one or more of a viewing angle for the final image or a depth-of-field for the final image.

[0015] According to the invention, producing the final image involves using the different views of the contact lens to form a final image which has a depth of field arranged along a curved surface of a contact lens to be inspected.

[0016] In some other embodiments of the inspection system according to the invention, the photodetector is a Charge-Coupled Device (CCD) array.

[0017] A further aspect of the invention is directed to a method for inspecting a contact lens according to claim 3.

[0018] According to the invention, generating the electronic plenoptic image by the plenoptic camera comprises:

receiving light from a contact lens, particularly on a lens holder, at a lenslet array comprising optical elements and located between the objective lens and a photodetector of the plenoptic camera, wherein each optical element in the lenslet array receives light from the contact lens field from a different angle than the other optical elements in the lenslet array and directs a different view of the contact lens field onto the photodetector.

[0019] In particular, each different view of the contact lens field is received at a separate location on the pho-

photodetector to produce a multidimensional array of different views of the contact lens field at the photodetector.

[0020] According to the invention, the step of receiving light from the contact lens at the lenslet array comprises receiving light from the contact lens by passing through an objective lens.

[0021] In some additional embodiments of the method according to the invention, the photodetector is a Charge-Coupled Device (CCD) array.

[0022] According to the invention, the method further comprises processing the different views of the contact lens field received by the photodetector to produce a final image.

[0023] In some other embodiments of the method according to the invention, producing the final image involves using the different views of the contact lens to adjust one or more of the following:

- a viewing angle for the final image; or
- a depth-of-field for the final image.

[0024] According to the invention, producing the final image involves using the different views of the contact lens to form a final image which has a plane of focus arranged along the curved surface of the contact lens.

[0025] On the contrary to conventional cameras, which fail to capture a large amount of optical information, the plenoptic camera captures information about the directional distribution of light rays entering the camera. During operation, a conventional digital camera captures a two-dimensional (2D) image representing a total amount of light which strikes each point on a planar photosensor within the camera, whereas the plenoptic image produced by the plenoptic camera contains information about the directional distribution of the light that strikes the photosensor in the plenoptic camera. Plenoptic image data may be represented or encoded in any of a number of different ways, including (but not limited to) as a 4D image, as a 2D array of 2D disk images such as known in the art, as a 2D array of 2D images of a contact lens taken from different perspectives such as would be captured by an array of cameras, and as any combination of these.

[0026] Whichever representation is used, plenoptic image data captured by a plenoptic camera may be processed to produce a 2D image that is suitable for display or output. Such plenoptic processing can include (but is not limited to) generating refocused images of a contact lens, generating perspective views of a contact lens, generating all-in-focus or extended depth of field (EDOF) images, generating perspective views of a contact lens, and/or any combination of these. Additionally, such generated 2D images may be modified or annotated based on the results of analysis of the plenoptic image data performed by algorithms that process the captured plenoptic image data. Plenoptic image data captured by the plenoptic camera contains information from which the range of depths captured is related to the set of pos-

sible 2D images which may be rendered from (or projected from) the captured plenoptic image data.

[0027] The 2D image may be refocused to a particular scene depth, and the scene depth to which it is refocused may be the same as or different from the scene depth which is optically in focus.

[0028] Similarly to a conventional camera, the plenoptic camera generally includes an objective lens which receives light from objects in an object field and directs the received light onto an image plane of the camera. It also includes a photodetector located at the image plane of the camera, which captures the received light to produce an image. However, unlike a conventional camera, the plenoptic camera additionally includes a lenslet array which may be located in front of the objective lens, or particularly between the object field and the objective lens. Each optical element in this lenslet array therefore receives light from the object field from a different angle than the other optical elements in the lenslet array, and consequently directs a different view of the object field into the objective lens. In this way, the photodetector receives a different view of the object field from each optical element in the lenslet array.

[0029] The present inspection system and method has the advantage of allowing for a retrospective focus of the electronic plenoptic image taken. This retrospective refocus of the plenoptic image is particularly advantageous for the inspection of contact lenses which have a curved surface. Additionally, this system and method is particularly advantageous when the contact lens is immersed in a liquid in an inspection container. When the contact lens is introduced into the inspection container, the contact lens may be located at a position differing from the rest position in the container (for example the contact lens may be swimming in the liquid it is immersed in), thereby being out of the depth of field of a conventional camera. The electronic plenoptic image is however refocused on the curved surface for inspection.

[0030] Additionally, the electronic plenoptic data retrieved by the plenoptic camera is used for forming a final image of the contact lens in which final image the focus plane is located along the curved surface, either front surface or the back surface, of the contact lens. In other words, for each point considered along the curved surface of the contact lens, the data is computed so to have a plane of focus at the considered curved surface. The number of points to be computed depends on the accuracy of the final image and of the inherent depth of field of the plenoptic camera system. The higher the depth of field of the camera system, the less points need to be computed from the raw data from the plenoptic image data.

[0031] The afore-mentioned embodiments are practical embodiments of the inspection system for contact lenses, in particular for soft contact lenses.

[0032] Further embodiments and advantages become apparent from the following description of detailed embodiments of the inspection system and method for in-

specting a contact lens according to the invention with the aid of the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0033]

FIG. 1 illustrates in an exemplary embodiment of the light paths in a plenoptic camera, which is not covered by the subject-matter of the claims.

FIG. 2 illustrates a schematic view of a plenoptic camera according to one embodiment, which is not covered by the subject-matter of the claims.

Fig. 3 shows an embodiment of a contact lens inspection system according to the invention.

DETAILED DESCRIPTION OF EMBODIMENTS

[0034] The subject matter is now described with reference to the drawings, wherein like reference numerals are used to refer to like elements throughout. In the following description, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the subject matter. It can be evident, however, that subject matter embodiments can be practiced without these specific details.

[0035] In contrast to a conventional camera, a "plenoptic" camera samples the four-dimensional (4D) optical phase space or light field and in doing so captures information about the directional distribution of the light rays. An example of such plenoptic camera is described in, R., Levoy, M., Bredif, M., Duval, G., Horowitz, M. and Hanrahan, P., "Light Field Photography with a Hand-Held Plenoptic Camera," Stanford University Computer Science Tech Report CSTR 2005-02, April 2005. This paper describes plenoptic camera designs based on modifications to a conventional digital camera.

[0036] As illustrated on Fig. 1, the lenslet array 11 comprises a plurality of microlenses 201, 202 and a group of photosensors 2010, 2020 of the photodetector 13 is optically associated with each microlens 201, 202 of the lenslet array 11. For example, on Fig. 1, the group of photosensors 2010 is associated with the microlens 201 and the group of photosensors 2020 is associated with the microlens 202. Each group of photosensors associated with a microlens corresponds to a micro-image associated with the corresponding microlens. The number of views of a same point 20, 21 of the contact lens acquired with the plenoptic camera 1 corresponds to the number of photosensors optically associated with one microlens as, thanks to the geometry of the microlens, a same point of the contact lens is viewed according to different angles. This means that each photosensor optically associated with a given microlens acquires data representative of a specific view of a point of the contact lens. The number of views of the contact lens acquired

with the plenoptic camera corresponds to the number of pixels associated with each (i.e. under each) microlens of the lenslet array 11. The number of photosensors optically associated with one microlens is advantageously the same for each microlens of the lenslet array 11. As illustrated, the ray of light 200 coming from the acquired contact lens, from the point 20 more specifically, passes through the objective lens 10 of the plenoptic camera 1, and the lenslet array 11 before reaching the photodetector 13, i.e. the photosensor 2001 of the group 2010. In a same way, the rays of light 210, 211 coming from the acquired contact lens, from the point 21 more specifically, passes through the objective lens 10 of the plenoptic camera 1 and the lenslet array 11 before reaching the photodetector 13, i.e. the photosensor 2101 of the group 2020 or a photosensor of the group 2010.

[0037] Different views of the contact lens are obtained by demultiplexing and demosaicing the raw image of the contact lens, pixels of the raw image corresponding to the photosensors of the photodetector 13. To obtain a determined view, the pixels of this determined view are collected from the raw image. For example, pixels associated with the photosensors 2001 and 2101 belong to a same view as they are located in a same position relatively to the center of the group of photosensors they each belong to, i.e. the groups 2010 and 2020 respectively.

[0038] Figure 2 shows a schematic view of a plenoptic camera 1 according to a particular embodiment, which is not covered by the subject-matter of the claims. The plenoptic camera comprises a lens unit 101 (corresponding to an optical assembly) and a camera body 102.

[0039] The lens unit 101 is advantageously adapted to be associated with the camera body 102. The camera body 102 comprises a photodetector 13, which comprises a plurality m of photosensors 131, 132, 133 to 13 m . Each photosensor corresponds to a pixel of the raw image of the contact lens acquired with the photodetector 13, with each pixel encompassing a part (also called a point) of the contact lens. For purposes of illustration, the photodetector 1313 is shown with a relative small number of photosensors 131 to 13 m . Naturally, the number of photosensors is not limited by the illustration of Fig. 2 but extends to any number of photosensors, for example several millions of photosensors. For example in a 12.4 megapixel camera, a pixel will correspond to a photosensor. An optional filter array 12 may be arranged on the photosensors array 13.

[0040] The camera body 102 also comprises a lenslet array being formed by a microlens array 11 comprising n microlenses 111, 112 to 11 n , n being an integer greater than or equal to 2. For purposes of illustration, the microlens array 11 is shown with a relative small number of microlenses, but the number of microlenses may extend up to several million of microlenses. A group of photosensors of the photodetector 13 are optically associated with each microlens 111 to 11 n of the microlens array 11. For example, each microlens 111 to 11 n of the mic-

rolens array 11 is sized to correspond to an array of 2x2, 4x4 or 10x10 photosensors. A group of photosensors associated with a microlens (or said differently, a group of photosensors under the microlens) form a micro-image associated with this microlens, each photosensor of the group of photosensors forming a pixel of the micro-image. Each photosensor of the plurality of photosensors optically associated with one single microlens enables it to acquire raw data representative of a pixel of the contact lens according to one position (acquisition of as many parallaxes as pixels).

[0041] In the present embodiment, the lens unit 101 and the camera body 102 collectively form one single body and are assembled without being detachable. They may, however, be designed differently.

[0042] The lens unit 101 comprises a camera lens, the objective lens 10, which is formed of one or more lens elements, only one lens element 10 being depicted in Fig. 2 for clarity purpose. The light coming from the contact lens to be acquired with the plenoptic camera and entering the plenoptic camera crosses through the objective lens 10, subsequently through the microlens array 11 and then hitting the photodetector 13.

[0043] The plenoptic camera 1 particularly comprises a hardware component 103 configured for controlling the plenoptic camera 1 and for electronically processing the electronic plenoptic image of the contact lens and configured for refocusing the image. The component 103 may particularly be configured for detecting a change in one or more parameters of the camera lens 10, for example a change of the focal length of the camera lens and/or a change of the focussing distance occurring when focalizing or zooming. The component 103 may be comprised in the camera body 102 or in the lens unit 101. The component 103 advantageously comprises one or several processors 1031 associated with a memory, for example a Random Access Memory or RAM 1032 comprising one or more registers. The memory stores instructions of one or more processes implementing the method of controlling the plenoptic camera 1. The component 103 can also receive and/or transmit data to and/or from sources remote from the plenoptic camera 1.

[0044] According to a variant, the component 103 is not comprised in the plenoptic camera 1 but connected to the plenoptic camera 1 via a wired connection (for example via USB (Universal Serial Bus)) or via a wireless connection (for example via Bluetooth, Wi-Fi). According to this variant, the component 103 comprises a transmitter to exchange data with the plenoptic camera 1.

[0045] The array of pictures is captured by photosensors array 13, which is particularly a CCD array, is processed by processing device 103 to produce a final image. By mixing the available images appropriately, processing device 103 can achieve various "plenoptic" effects, such as refocusing an image, reducing noise, adjusting the viewing angle, and adjusting the depth-of-field for the final image. Alternatively, several different views of the array of pictures received at the photosensors 13 may

be processed to have acceptable focus for each level of focus of the contact lens. These images may be combined to achieve a final image focused along the curved surface of the contact lens.

[0046] Fig. 3 shows a schematic view of an embodiment of a contact lens inspection system according to the invention. The contact lens inspection system 300 comprises a light source 40 for illuminating a contact lens, in particular a soft contact lens, which is held in a container 30 (lens holder) in liquid, for example water. The light source 40 is arranged at a first longitudinal end of the container 30 near the container bottom 33, and illuminates the soft contact lens with light. Container bottom 33 is transparent to the light impinging thereon, and in the embodiment has a slightly convex outer surface 31. The soft contact lens may be supported inside the container 30 on a slightly concave inner surface 32 of container bottom 33, this concave inner surface 32 forming a support for the soft contact lens. The other longitudinal end of the container 30 can be either open, or may be provided with a lid which is transparent with respect to the collimated light impinging on the container 30. At that longitudinal end of the container 30 opposite to the end where the light source 40 is arranged, there is arranged a plenoptic camera 1 comprising an objective lens 10, a lenslet array 11 and a photodetector 13, for example a CCD-sensor or CMOS-sensor. The camera 1 is connected via a data line 50 with processing device 103 for processing the array of pictures captured by the photodetector 13 of the camera 1.

[0047] For inspecting a contact lens, the contact lens is held in the container 30 and illuminated by the light source 40. An electronic plenoptic image of the illuminated contact lens is then generated by the plenoptic camera 1. The plenoptic image comprises different views of a contact lens field as received by the photodetector due to the lenslet array 11 comprising optical elements located between the objective lens 10 and the photodetector 13 of the plenoptic camera 1. Each optical element in the lenslet array 11 receives light from the contact lens from a different angle than the other optical elements in the lenslet array 11 and directs a different view of the contact lens onto the photodetector 13.

[0048] The photodetector 13 receives light from the lenslet array 11. The photodetector 13 receives a different view of the contact lens field from each optical element in the lenslet array 11 and each different view of the contact lens field is received at a separate location on the photodetector 13 to produce a multidimensional array of different views of the contact lens field at the photodetector 13, the electronic plenoptic image.

[0049] The electronic plenoptic image of the contact lens is then processed by an electronic processing unit 103 which is configured for refocusing the electronic plenoptic image of the contact lens. In particular, the electronic processing unit 103 is configured to adjust the viewing angle for the final image or the depth-of-field for the final image. Additionally, the electronic plenoptic image

data is processed by the electronic processing unit 103 to produce a final image which has a plane of focus which is arranged along the curved surface - front surface or back surface - of the contact lens by adjusting the focus at each considered point along the curved surface of the contact lens and superposing the computed images to form a final image in which the contact lens surface is sharp.

[0050] As mentioned above, the present invention can achieve various "plenoptic" effects, such as refocusing, reducing noise, adjusting the viewing angle, and adjusting the depth-of-field for the image.

Claims

1. A contact lens inspection system (300), in particular for soft contact lenses, comprising:

a light source (40) configured for illuminating a contact lens to be inspected;

a camera (1) configured for producing an electronic image of the contact lens;

a processing unit (103) configured for electronically processing the electronic image of the contact lens,

characterized in that the camera (1) is a plenoptic camera (1) having an objective lens (10), a lenslet array (11) and a photodetector (13), and being configured for producing an electronic plenoptic image of the contact lens,

and in that the processing unit (103) is configured for electronically processing and for refocusing the electronic plenoptic image of the contact lens,

wherein the processing unit (103) is adapted for processing different views of the contact lens received by the photodetector (13) to produce a final image, and

wherein producing the final image involves using the different views of the contact lens to form a final image which has a plane of focus arranged along a curved surface of the contact lens to be inspected.

2. A contact lens inspection system according to claim 1, wherein the photodetector (13) is a Charge-Coupled Device (CCD) array.

3. A method for inspecting a contact lens, in particular a soft contact lens, the method comprising:

illuminating a contact lens to be inspected;
generating an electronic image of the contact lens by a camera (1) **characterized in that** the electronic image of the contact lens is generated by a plenoptic camera (1) comprising different views of the contact lens received by a photo-

detector (13) of the plenoptic camera (1); the method further comprising electronically processing the electronic plenoptic image of the contact lens by using different views of the contact lens to adjust a plane-of-focus, wherein generating the electronic plenoptic image by the plenoptic camera (1) comprises:

receiving light from the contact lens, particularly arranged on a lens holder, at a lenslet array (11), the lenslet array (11) comprising optical elements and being located between an objective lens (10) and the photodetector (13) of the plenoptic camera, wherein each optical element in the lenslet array (11) receives light from the contact lens from a different angle than the other optical elements in the lenslet array (11) and directs a different view of the contact lens onto the photodetector (13); and

the method further comprising processing the different views of the contact lens received by the photodetector (13) to produce a final image,

wherein producing the final image involves using the different views of the contact lens to form a final image which has a plane of focus arranged along a curved surface of the contact lens.

4. Method according to claim 3, wherein the photodetector (13) is a Charge-Coupled Device (CCD) array.

Patentansprüche

1. Kontaktlinsenprüfsystem (300), insbesondere für weiche Kontaktlinsen, umfassend:

eine Lichtquelle (40), die zum Beleuchten der zu prüfenden Kontaktlinse ausgelegt ist;

eine Kamera (1), die zum Erzeugen eines elektronischen Bildes der Kontaktlinse ausgelegt ist;

eine Verarbeitungseinheit (103), die zum elektronischen Verarbeiten des elektronischen Bildes der Kontaktlinse ausgelegt ist,

dadurch gekennzeichnet, dass die Kamera (1) eine plenoptische Kamera (1) mit einer Objektlinse (10), einem Mikrolinsenarray (11) und einem Fotodetektor (13) ist und zum Erzeugen eines elektronischen plenoptischen Bildes der Kontaktlinse ausgelegt ist.

und dadurch, dass die Verarbeitungseinheit (103) zum elektronischen Verarbeiten und zum Neufokussieren des elektronischen plenoptischen Bildes der Kontaktlinse ausgelegt ist, wobei die Verarbeitungseinheit (103) dazu eingerichtet ist, unterschiedliche, durch den Foto-

detektor (13) empfangene Ansichten der Kontaktlinse zu verarbeiten, um ein endgültiges Bild zu erzeugen, und
wobei das Erzeugen des endgültigen Bildes ein Verwenden der unterschiedlichen Ansichten der Kontaktlinse zur Erzeugung eines endgültigen Bildes umfasst, das eine Fokusebene aufweist, die entlang einer gekrümmten Oberfläche der zu prüfenden Kontaktlinse angeordnet ist.

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2. Kontaktlinsenprüfsystem nach Anspruch 1, wobei der Fotodetektor (13) ein Array von ladungsgekoppelten Bauelementen (CCD) ist.

3. Verfahren zur Prüfung einer Kontaktlinse, insbesondere einer weichen Kontaktlinse, wobei das Verfahren umfasst:

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Beleuchten einer zu prüfenden Kontaktlinse;
Erzeugen eines elektronischen Bildes der Kontaktlinse durch eine Kamera (1),

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dadurch gekennzeichnet, dass das elektronische Bild der Kontaktlinse durch eine plenoptische Kamera erzeugt wird und unterschiedliche Ansichten der Kontaktlinse umfasst, die durch einen Fotodetektor (13) der plenoptischen Kamera (1) empfangen werden; wobei das Verfahren ferner umfasst:

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elektronisches Verarbeiten des elektronischen plenoptischen Bildes der Kontaktlinse durch Verwenden der unterschiedlichen Ansichten der Kontaktlinse zum Anpassen einer Fokusebene,
wobei das Erzeugen des plenoptischen Bildes durch die plenoptische Kamera (1) umfasst:

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Empfangen von Licht von der insbesondere auf einem Linsenhalter angeordneten Kontaktlinse an einem Mikrolinsenarray (11), wobei das Mikrolinsenarray (11) optische Elemente umfasst und sich zwischen einer Objektlinse (10) und dem Fotodetektor (13) der plenoptischen Kamera befindet, wobei jedes optische Element im Mikrolinsenarray (11) Licht von der Kontaktlinse von einem anderen Winkel als die anderen optischen Elemente im Mikrolinsenarray (11) empfängt und eine unterschiedliche Ansicht der Kontaktlinse auf den Fotodetektor (13) richtet; und

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wobei das Verfahren ferner ein Verarbeiten der unterschiedlichen, durch den Fotodetektor (13) empfangenen Ansichten der Kontaktlinse umfasst,

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um ein endgültiges Bild zu erzeugen, wobei das Erzeugen des endgültigen Bildes ein Verwenden der unterschiedlichen Ansichten der Kontaktlinse zur Erzeugung eines endgültigen Bildes umfasst, das eine Fokusebene aufweist, die entlang einer gekrümmten Oberfläche der Kontaktlinse angeordnet ist.

4. Verfahren nach Anspruch 3, wobei der Fotodetektor (13) ein Array von ladungsgekoppelten Bauelementen (CCD) ist.

Revendications

1. Système d'inspection de lentilles de contact (300), en particulier pour lentilles de contact souples, comprenant :

une source de lumière (40) configurée pour éclairer une lentille de contact devant être inspectée ;

une caméra (1) configurée pour produire une image électronique de la lentille de contact ;

une unité de traitement (103) configurée pour traiter électroniquement l'image électronique de la lentille de contact,

caractérisé en ce que la caméra (1) est une caméra plenoptique (1) ayant un objectif (10), une matrice de microlentilles (11) et un photodétecteur (13), et étant configurée pour produire une image plenoptique électronique de la lentille de contact,

et en ce que l'unité de traitement (103) est configurée pour traiter électroniquement et pour refaire la mise au point de l'image plenoptique électronique de la lentille de contact,

dans lequel l'unité de traitement (103) est adaptée pour traiter différentes vues de la lentille de contact reçues par le photodétecteur (13) pour produire une image finale, et

dans lequel la production de l'image finale implique l'utilisation des différentes vues de la lentille de contact pour former une image finale qui a un plan de mise au point disposé le long d'une surface incurvée de la lentille de contact devant être inspectée.

2. Système d'inspection de lentilles de contact selon la revendication 1, dans lequel le photodétecteur (13) est une matrice de dispositifs à couplage de charge (CCD).

3. Procédé destiné à inspecter une lentille de contact, en particulier une lentille de contact souple, le procédé comprenant :

l'éclairage d'une lentille de contact devant être inspectée ;

la génération d'une image électronique de la lentille de contact par une caméra (1),

caractérisé en ce que l'image électronique de la lentille de contact est générée par une caméra plénoptique (1) comprenant différentes vues de la lentille de contact reçues par un photodétecteur (13) de la caméra plénoptique (1) ; le procédé comprenant en outre le traitement électronique de l'image plénoptique électronique de la lentille de contact au moyen de différentes vues de la lentille de contact pour régler un plan de mise au point, dans lequel la génération de l'image plénoptique électronique par la caméra plénoptique (1) comprend :

la réception de lumière provenant de la lentille de contact, en particulier disposée sur un support de lentille, au niveau d'une matrice de microlentilles (11), la matrice de microlentilles (11) comprenant des éléments optiques et étant située entre un objectif (10) et le photodétecteur (13) de la caméra plénoptique, chaque élément optique de la matrice de microlentilles (11) recevant de la lumière provenant de la lentille de contact depuis un angle différent de celui des autres éléments optiques dans la matrice de microlentilles (11) et acheminant une vue différente de la lentille de contact sur le photodétecteur (13) ; et le procédé comprenant en outre le traitement des différentes vues de la lentille de contact reçues par le photodétecteur (13) pour produire une image finale, dans lequel la production de l'image finale implique l'utilisation des différentes vues de la lentille de contact pour former une image finale qui a un plan de mise au point disposé le long d'une surface incurvée de la lentille de contact.

4. Procédé selon la revendication 3, dans lequel le photodétecteur (13) est une matrice de dispositifs à couplage de charge (CCD).

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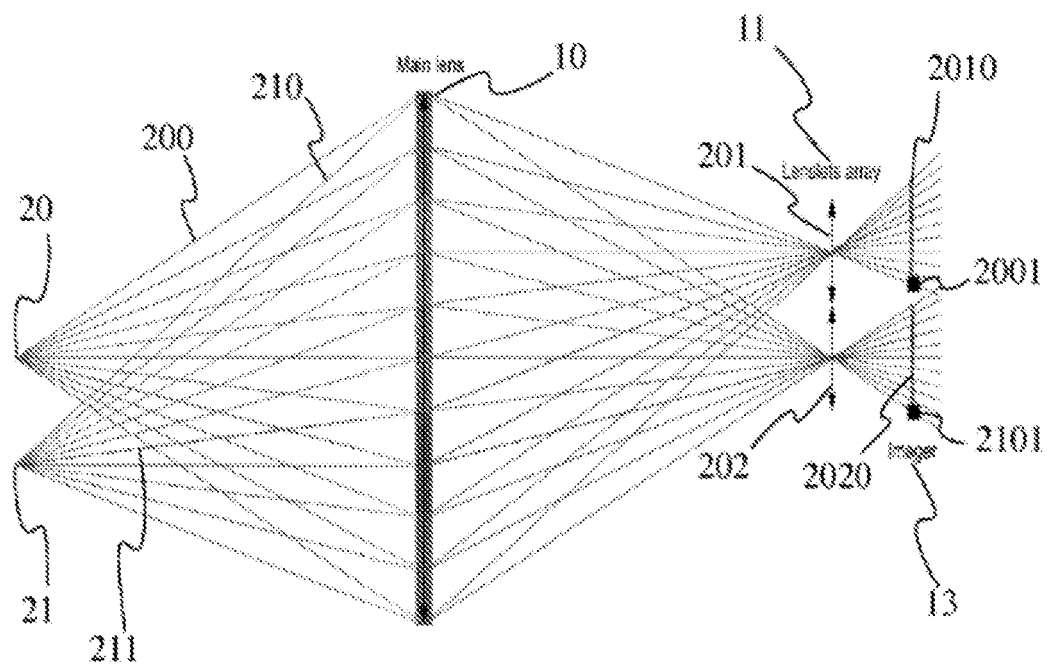


Fig. 1

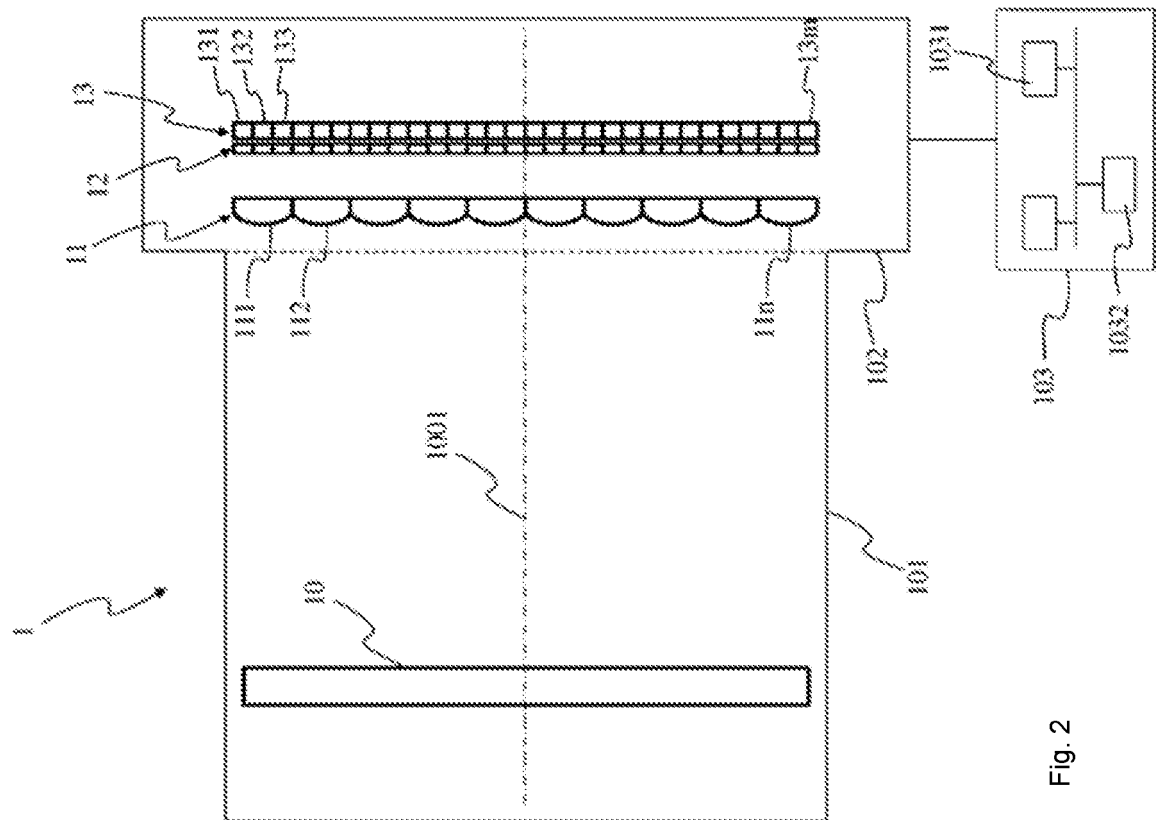


Fig. 2

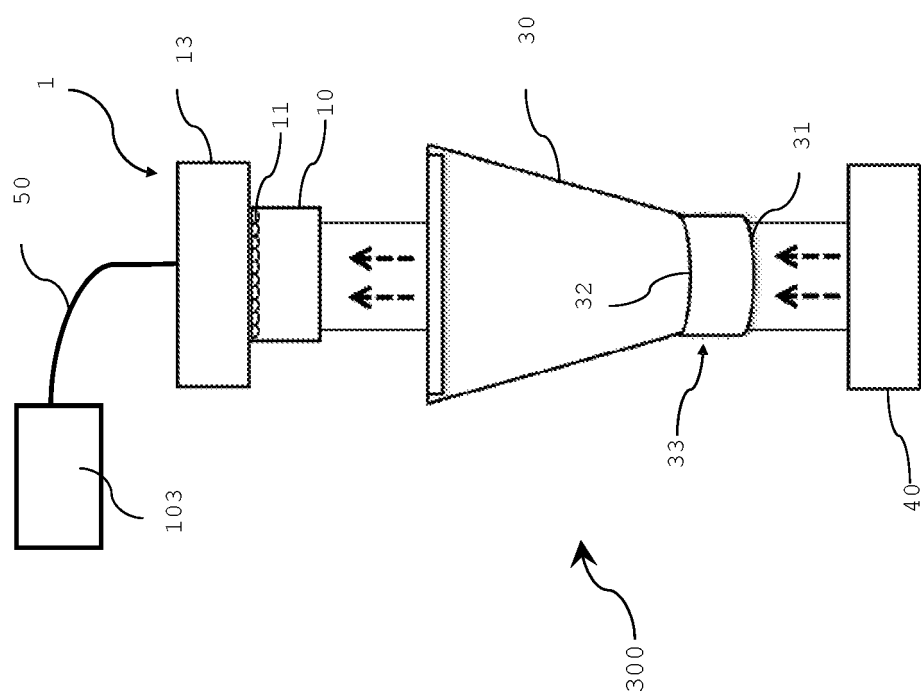


Fig. 3

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- WO 2009148862 A2 [0004]
- DE 102015201823 A1 [0005]
- WO 2015053712 A1 [0006]

Non-patent literature cited in the description

- LEVOY, M. ; BREDIF, M. ; DUVAL, G. ; HOROW-ITZ, M. ; HANRAHAN, P. Light Field Photography with a Hand-Held Plenoptic Camera. *Stanford University Computer Science Tech Report CSTR 2005-02*, April 2005 [0035]